Discharge vs. Drawdown *A Critical Diagnostic Tool for the API LNAPL Transmissivity Spreadsheet Tool*

Rangaramanujam Muthu

J Michael Hawthorne

H_2A Environmental, Ltd.

www.h2altd.com

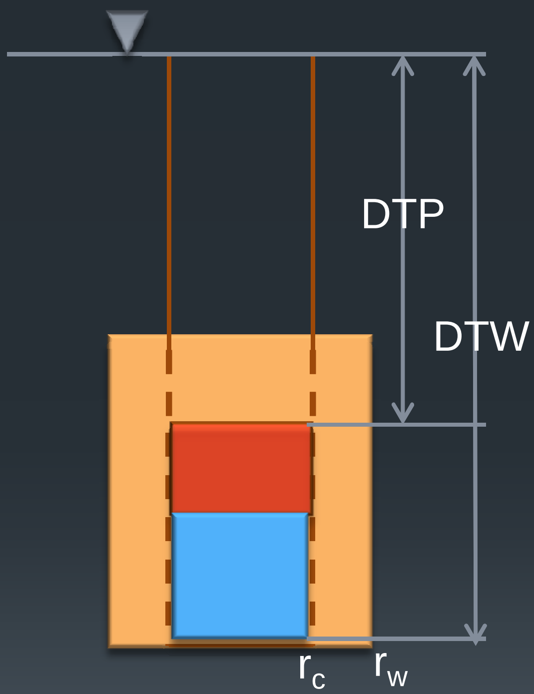
www.napl-ansr.com

API LNAPL Transmissivity Spreadsheet Tool

- Published in 2012 by American Petroleum Institute
- Facilitates the estimation of LNAPL transmissivity from Baildown Tests
- Contains multiple diagnostic tools:
  - ✓ Gauging data
  - ✓ Discharge vs. Drawdown
  - ✓ Drawdown vs. LNAPL Thickness
  - ✓ Drawdown vs. Time
  - ✓ Depth to Product/ Water vs. Discharge
  - ✓ LNAPL Thickness vs. Time
  - ✓ LNAPL Inflow Volume vs. Time

Discharge

- Discharge (or recharge) is calculated from the gauging data and effective well radius as,



$$Q_{ni} = \frac{\pi r_{ei}^2 (DTP_i - DTP_{i+1} + DTW_{i+1} - DTW_i)}{(t_{i+1} - t_i)}$$

Q_n – NAPL Discharge at time increment 'i'

r_e – Effective radius

DTP – Depth to Product

DTW – Depth to Water

t – Time

The equation accounts for increase in LNAPL storage volume over the time interval.

Note: The effective well radius <u>may not be constant</u> as it can change with the storage characteristics during recharge.

Drawdown

- Typically LNAPL drawdown is calculated as the change in air/NAPL (AN) interface as,

$$s_{ni} = DTP_i - DTP_0 - \Delta s_n$$

s_n – NAPL Drawdown at time increment 'i'

DTP – Depth to Product

Δs_n – Drawdown correction

Measured based on the change in DTP from the pre-test value (‘0’ subscript) along with any correction to account for non-equilibrium between formation and wellbore LNAPL.

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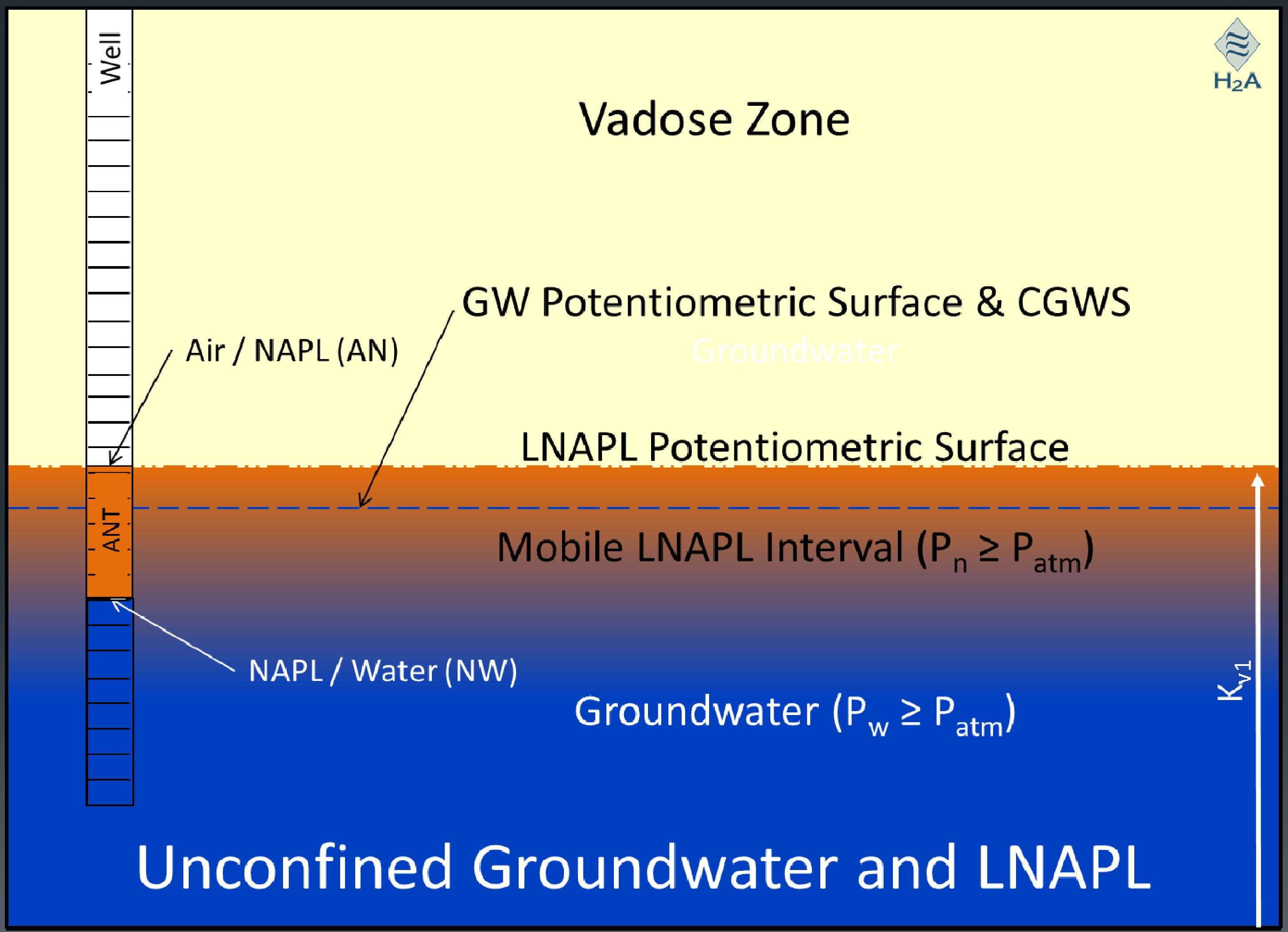
Discharge vs. Drawdown

- Scatter plot of LNAPL recharge into a well during a baildown test versus the LNAPL drawdown.

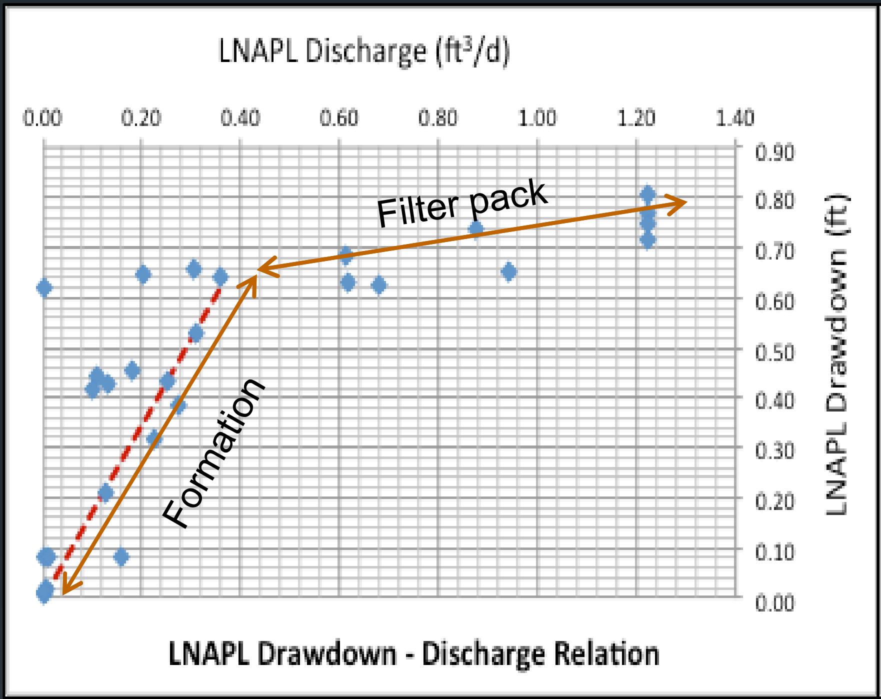
- Shape of the plot can be used to identify:
  - ✓ Unconfined, confined, or perched conditions
  - ✓ Borehole recharge from the filter pack
  - ✓ Equilibrium between formation and well LNAPL
  - ✓ Mobile LNAPL interval
  - ✓ Lithologic zones of mobile LNAPL

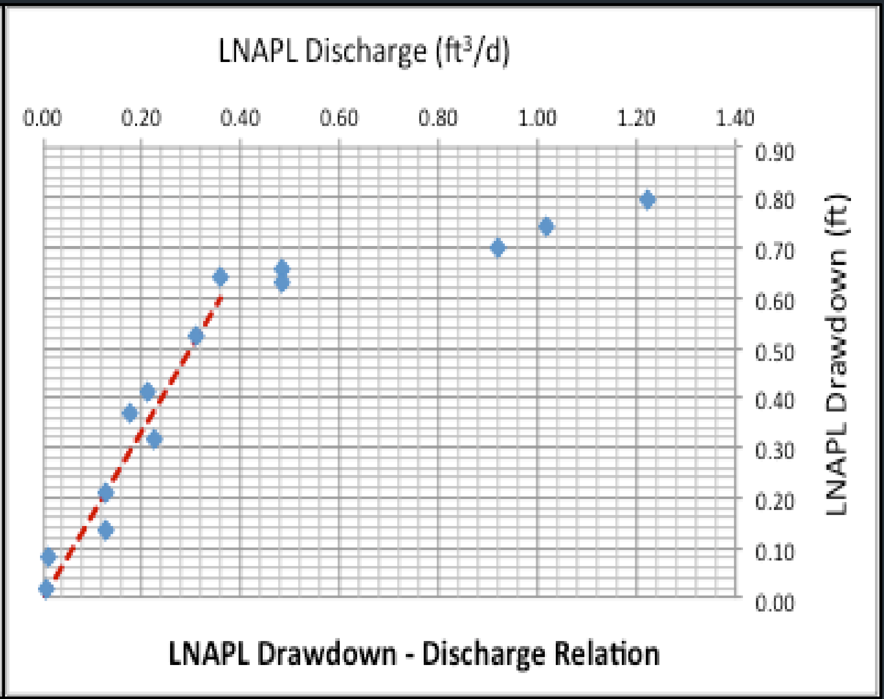
Examples

Unconfined Conditions – Conceptual Model



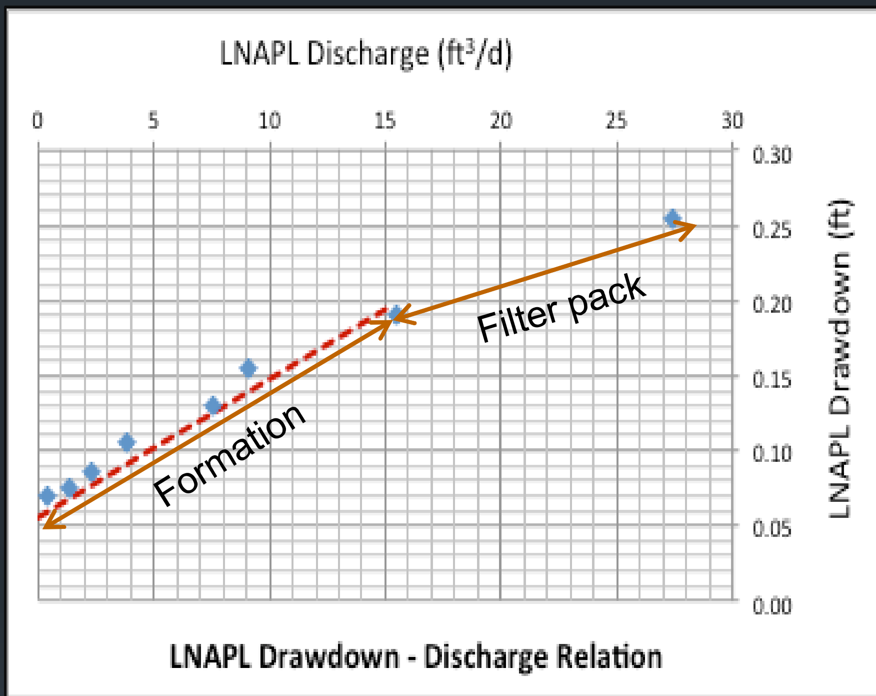
Unconfined Conditions

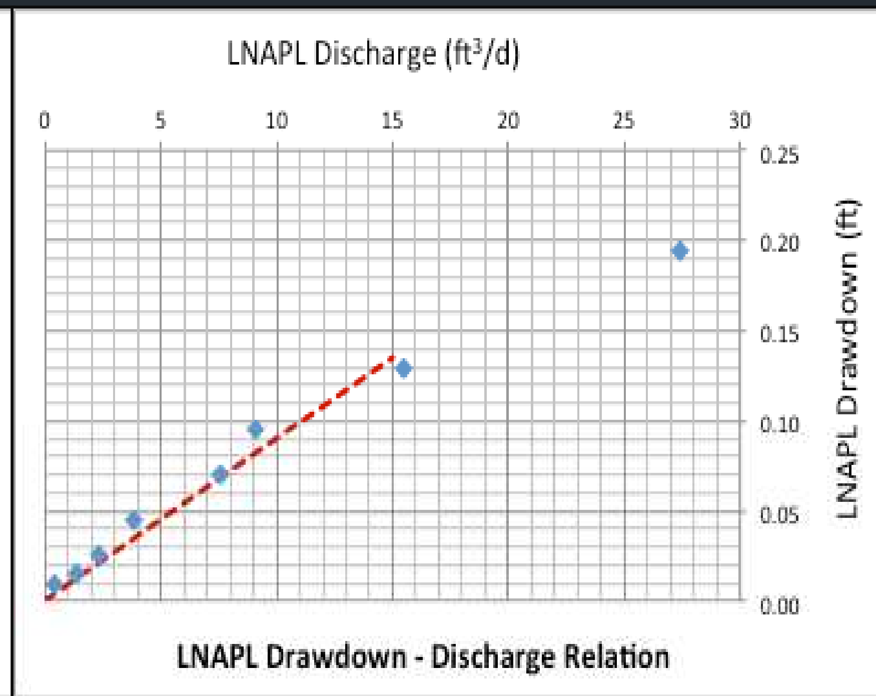




- Sand and gravel with intermittent silt and clay lens.
- Filter pack drainage significant.
- Linear trend but significant “noise” (scatter) in data
- Preprocessing the gauging data reduces the noise (e.g. remove zero/negative discharge, consider drawdown increment)
- T_n ~0.2 ft^2/d.

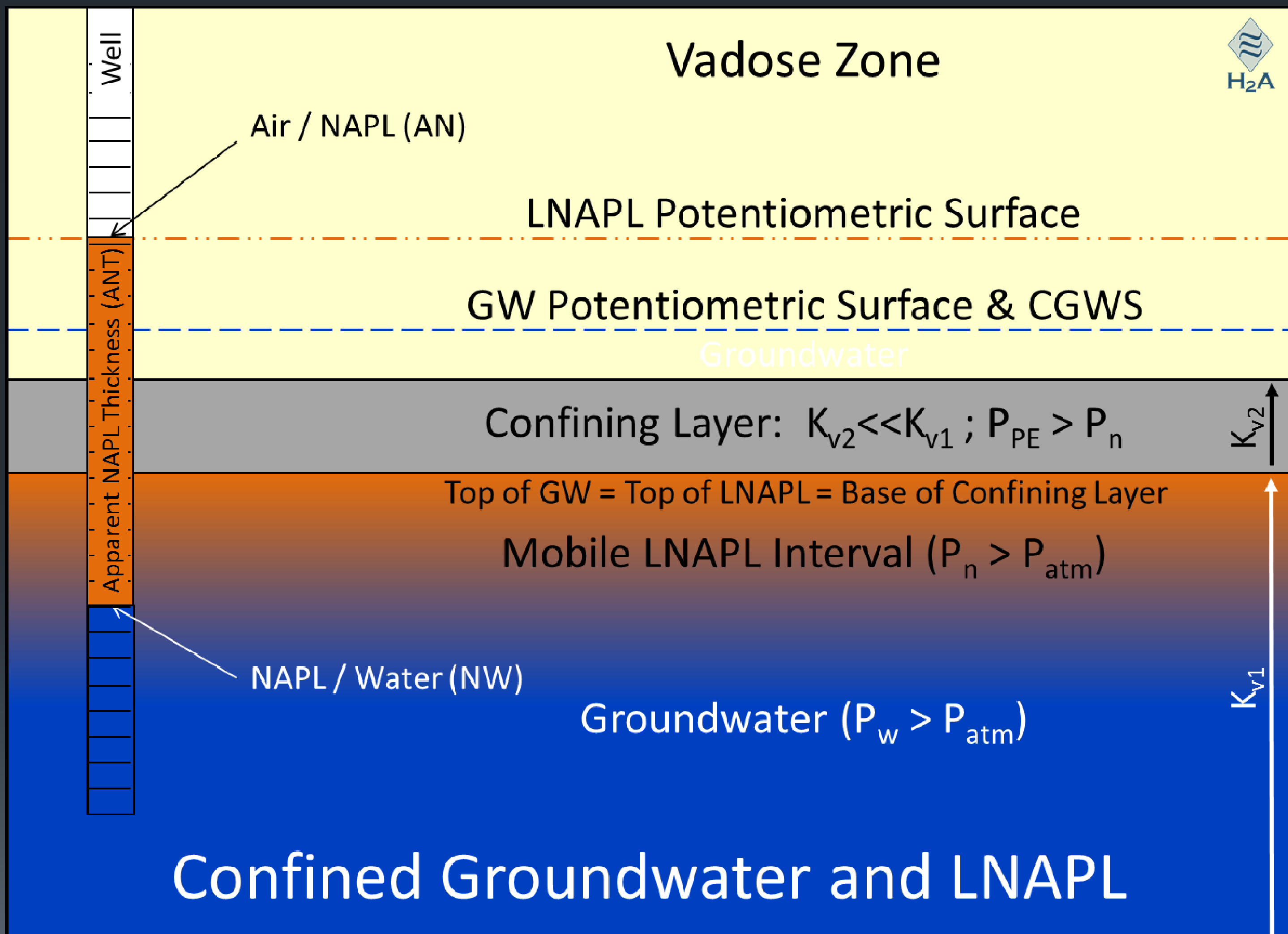
Unconfined Conditions



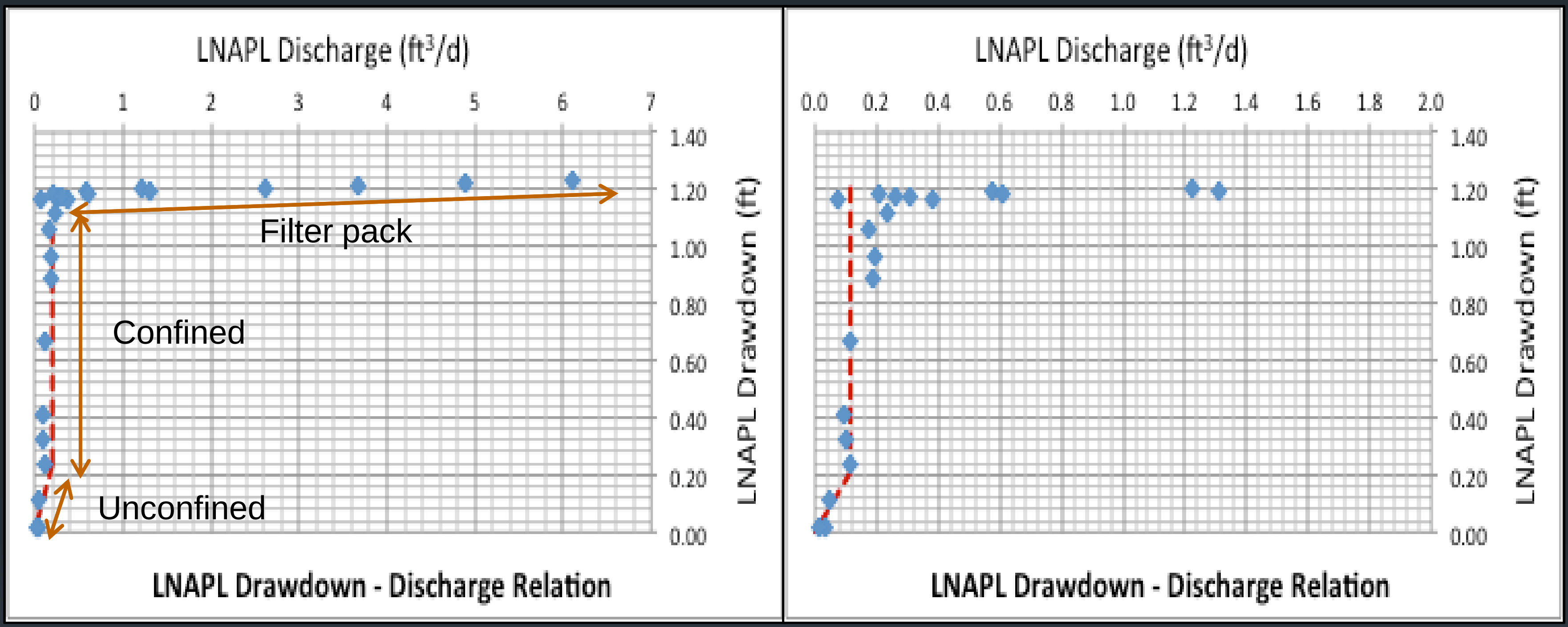


- Sand and gravel with intermittent silt and clay lens.
- Filter pack drainage not apparent.
- Well recharged within an hour.
- Drawdown adjustment ~ 0.06 ft (initial non-equilibrium).
- T_n ~ 16 ft^2/d (with adjustment) and ~20 ft^2/d (without) adjustment.

Confined Conditions – Conceptual Model

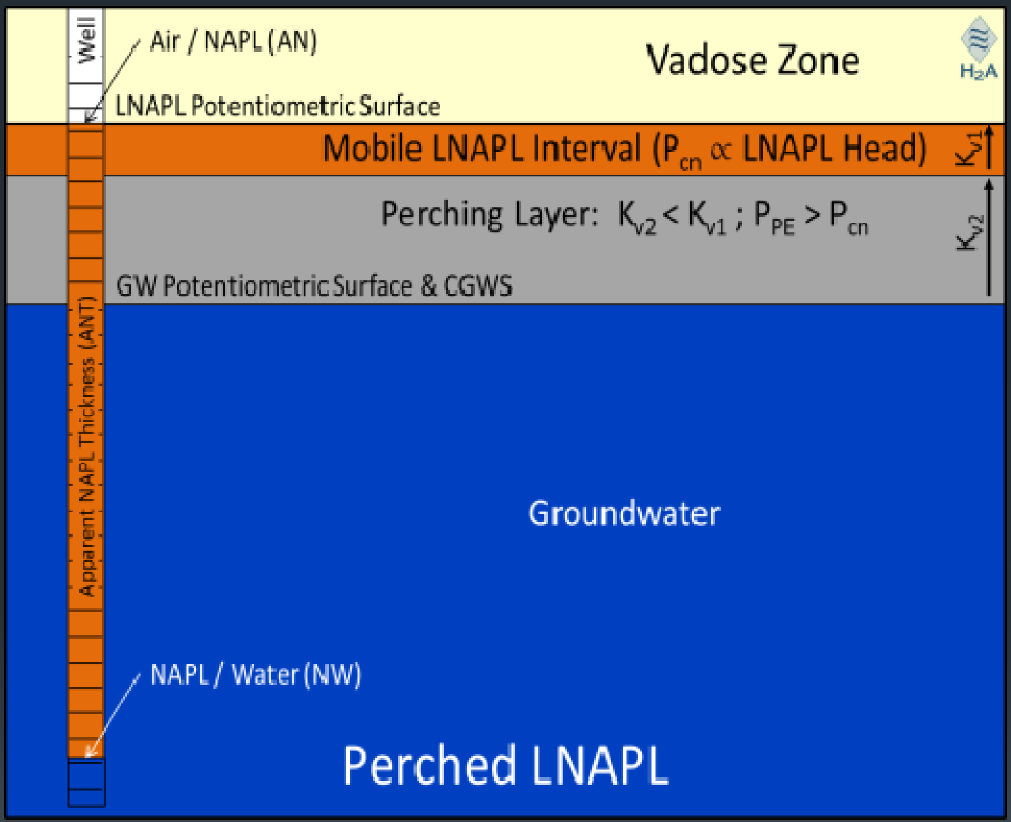


Confined Conditions



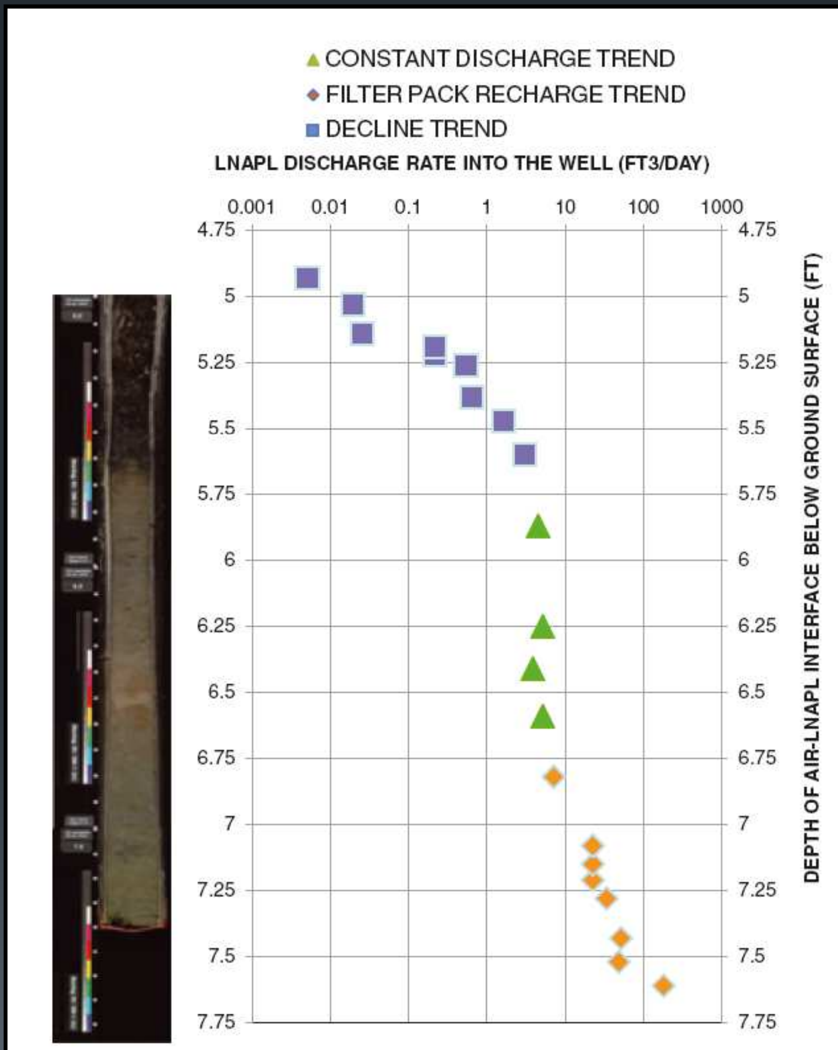
- Sand and gravel with intermittent silt and clay lens.
- Filter pack drainage significant.
- Constant discharge rate ~ 0.016 ft^3/d.
- T_n ~ 0.04 ft^2/d.
- As ANT increases to contact the mobile LNAPL, inflow is retarded and decreases linearly with drawdown (unconfined behavior).

Perched Conditions – Conceptual Model



- Discharge vs. drawdown relationship similar to confined conditions.
- To distinguish between the two,
  - ✓ Detailed Soil Profiles,
  - ✓ LIF/PID data,
  - ✓ Equilibrium gauging data.

Perched Conditions



From Kirkman et al. (GWMR, Volume 33, Issue 1, Winter 2013)

- Soil core analysis indicated perched LNAPL in gravelly fill overlying native fine silty clay
- Baildown test conducted in 2003.
- Discharge trends:
  Orange – Filter pack
  Green – Constant discharge
  Blue – Decreasing discharge
- Perched condition based on,
  - ✓ Decreasing LNAPL-water interface
  - ✓ LNAPL-water interface remained within the silty clay and did not intersect any soil contact.

Summary

- Discharge vs drawdown graphs are an excellent diagnostic tool to identify hydrogeologic conditions, equilibrium, mobile NAPL interval, lithologic zones of mobile NAPL.
- Discharge estimated from change in DTP and DTW along with effective radius.
- Drawdown estimated with respect to change in Air/NAPL interface (measured as DTP) from initial level.
- Data processing (noise, filter pack drainage, increments, drawdown adjustment).
- Unconfined conditions – Linear discharge vs. drawdown relationship.
- Confined/perched conditions – Constant discharge vs. decreasing drawdown not accounting for filter pack.

Additional Information

- API LNAPL Transmissivity Workbook: Calculation of LNAPL Transmissivity from Baildown Test Data

  www.api.org/lnapl

- Discharge vs. Drawdown (DvD) Graphs - Graphical Analysis of Unconfined LNAPL Baildown Test Data

  Vol 1, Issue 4, April 2011

  www.napl-ansr.com

Thank you